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An efficient 3D traveltime calculation using coarse-grid mesh for shallow source

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3D Kirchhoff pre-stack depth migration requires an efficient algorithm to compute first-arrival traveltimes. In this paper, we exploited a wave-equation-based traveltime calculation algorithm, which is called the suppressed wave equation estimation of traveltime (SWEET), and the equivalent source distribution (ESD) algorithm. The SWEET algorithm is to solve the Laplace-domain wave equation to calculate first-arrival traveltimes and the corresponding amplitudes. In this algorithm, a seismic trace is approximated as a series of weighted spikes. By solving the wave equation in the Laplace domain, all the spikes except the first-arrival event are attenuated and become negligible. Thus, a series of weighted spikes can be approximated as a single spike. As a result, the first-arrival travetime can be extracted from the solution of wave equation in the Laplace domain. However, if a real source is located at shallow depth close to free surface, we cannot accurately calculate the wavefield using coarse grid spacing. So, we need an additional algorithm to correctly simulate the shallow source even for the coarse grid mesh. The ESD algorithm is a method to define a set of distributed nodal point sources that approximate a point source at the inter-nodal location in large grid spacing velocity model. Thanks to the ESD algorithm, we can efficiently calculate the first-arrival traveltimes of wave emitted from shallow source point even when using a coarse-grid mesh. The forward modeling of Laplace-domain wave equation is formulated using finite-element method and solved by preconditioned conjugate gradient method. To suppress unwanted edge reflections, we adopt a perfectly matched layer (PML) boundary condition. To verify our algorithm, we compare the numerical traveltime calculated by the proposed algorithm with analytical traveltime for a 3D homogeneous half-space medium. The ESD algorithm correctly simulates shallow point source and provides more accurate traveltimes. The proposed algorithm is applied to the SEG/EAGE 3D salt model and shows reasonable results. Our algorithm can be used for implementing an efficient 3D Kirchhoff pre-stack depth migration.